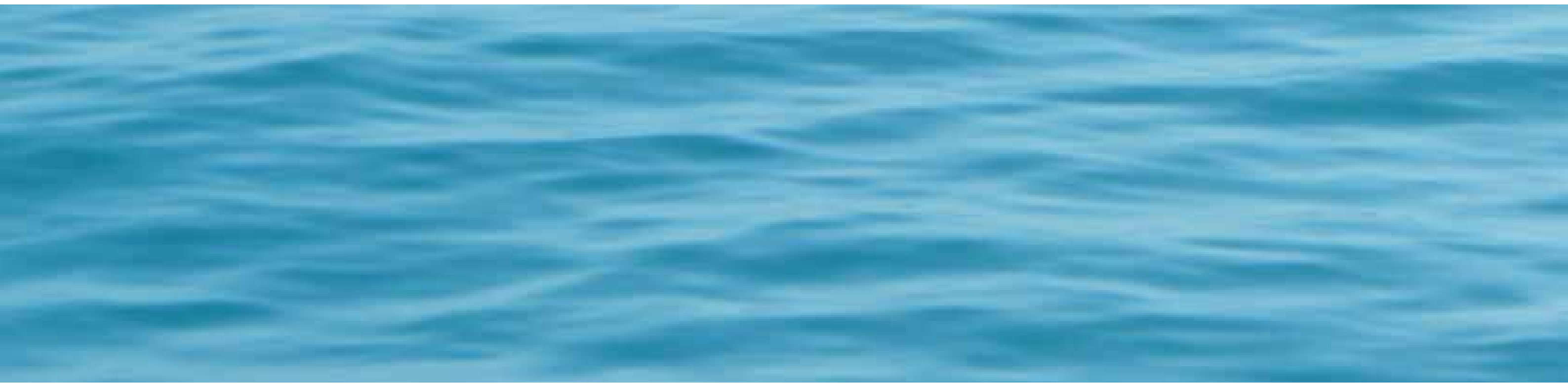
Large diameter pipes (HDPE) delivered in long lengths from Pipelife Stathelle. The long length pipe concept is especially suitable for marine solutions serving power plants, desalination, water and wastewater management, as well as transmission line protection.

PIPELIFE
always part of your life



1. INTRODUCTION TO PIPELIFE NORWAY 4

2. PIPE RANGE OVERVIEW 5

3. PIPELIFE'S UNIQUE PRODUCTION AND ITS BENEFITS 5

3.1 Long length 5

3.2 Large diameter solid wall pipe 5

3.3 Nitrogen 5

3.4 SDR classes 5

3.5 Pipe delivery by sea 6

4. FITTINGS RANGE 6

4.1 Electrofusion saddles 6

4.2 PE Fittings 7

4.3 Special reinforced PE fittings 8

5. PE MATERIAL PROPERTIES 8

5.1 General 8

5.2 PE raw material classification 8

5.3 PE pipe classification 8

5.4 PE material properties 8

5.5 E-modulus 10

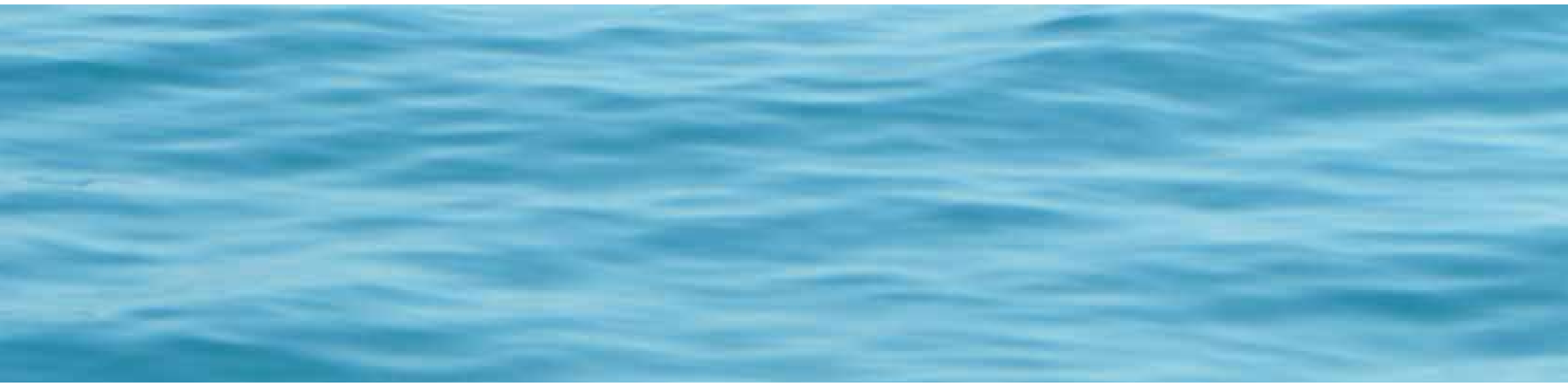
5.6 Thermal expansion/anchoring of PE pipes 10

5.7 Diffusion 11

5.8 Notch sensivity 12

5.9 Abrasion resistance 12

5.10 Chemical resistance 12



6. WELDING......12

6.1 Butt fusion welding......12

7. ADVANTAGES OF LLLD CONCEPT......13

8. FOCUS IN MARINE PROJECTS......14

8.1 Marine installations......14

8.2 Ballasting......16

8.3 Trenching and backfilling......16

9. ENGINEERING SUPPORT......18

9.1 Design guidelines......18

9.2 Installation guidelines......18

10. SELECTION OF SDR CLASS......18

11. TOLERANCES IN PRODUCTION......19

11.1 Pipe production tolerances......19

11.2 Fittings production tolerances......21

12. DISCLAIMER......21

13. ENCLOSURE 1: PIPE PRODUCTION RANGE......22

14. ENCLOSURE 2: FLANGE CONNECTION TABLE......23

15. ENCLOSURE 3: PIPELIFE MARINE PROJECT REFERENCES......24

15.1 Power Plant Project highlight......24

15.2 Sewer outfall project highlight......24

15.3 Desalination project highlight......24

1. Introduction to Pipelife Norge AS

Pipelife Norge AS operates in Norway. The company's Stathelle plant is located on the shore of a protected narrow fjord, providing the perfect environment for long length pipe productionThe plant's position on the coast delivers various benefits such as continuous production, and pipe length limited only by the size of the fjord itself and the diameter of the pipe.

The plant has its own large storage area on land and on sea, as well as a dedicated wharf for ocean going tugs. Norway's infrastructure guarantees a stable energy supply, and reliable provision of materials necessary for the production process.

The production line used to manufacture the pipes is of the highest quality, made with special modifications which enable unique advantages explained further in Chapter 3.

Picture 1 - Pipelife Norge Stathelle plant

2. Pipe range overview

Production range at a glance:

Material: High Density Polyethylene (HDPE)

Pipe diameter: OD25-2500 mm

Lengths: Standard delivery length from 12 up to 620 m. (depending on the size, length might be longer. Please contact us for more details)

Standard Dimensional Ratio (SDR) classes: SDR all standard values (7.4 - 33) with flexibility as described in chapter 3.4. in detail (SDR value = Pipe OD/pipe wall thickness).

Full details are given in Enclosure 1: Pipe production range.

3. Pipelife's unique production process and its benefits

In 2004 Pipelife installed the world's first PE pressure pipe extrusion system, enabling the manufacture of PE pipes up to OD2000mm. The diameter range expansion continued with the installation of an OD2500m extrusion line in February 2012, allowing us to deliver pipes in OD2100mm, OD2300mm and OD2500mm. Pipelife continues to pioneer the long length large diameter PE system, pushing industry borders to provide its clients with new opportunities.

The Long Length Large Diameter (LLLD) concept was developed in the Pipelife Norge AS plant, and has since proved a huge success due to the unique advantages the approach delivers, explained in detail in Chapter 7.

Pipelife produces pipes using a modified pressure calibration extrusion line. To ensure that the pipe is of the highest quality a special process is used. Some points are mentioned in the following chapters:

3.1 Long length

Pipes are produced by continuous extrusion, and are cut to the desired length in the process. This method of production ensures consistent quality, with no interruptions in the process. Pipe sections, which normally measure 550m maximum, are sealed off at both ends with PE end plugs or flange connections. Closed pipe sections are then towed by the tugboat to the marine destination.

Length is limited mainly by the size of the fjord, but maximum lengths can exceed the size of the fjord depending on the diameter of the pipe. Please contact Pipelife for more information for a specific project.

3.2 Large diameter solid wall pipe

The plant at Stathelle can produce up to OD2500mm solid wall pipe, produced according to "EN12201 – 2:2011 + A1:2013 – Plastic piping systems for water supply, and for drainage and sewerage under pressure" and "ISO 4427-2 – Plastic piping systems – Polyethylene (PE) pipes and fittings for water supply".

3.3 Nitrogen

Pressure inside the sealed pipe during production is maintained with inert Nitrogen gas. Nitrogen gas ensures that anti-oxidation additives in the raw material are not destroyed by heat during production which increases the longevity of the pipes.

Oxidation Induction Time (OIT) tests have shown results that are 40% better when nitrogen is used, as opposed to air.

3.4 SDR classes

Pipelife's production process enables additional benefits when determining possible SDR values for the project.

Pipelife can produce standard SDR ratios (e.g. 11, 17, 21, 26, 33) and in addition almost all other non-standard values (e.g. 13, 14, 22, 23, 24, 25, 30).

Another benefit of Pipelife's unique process is that the SDR class can be varied throughout the length of the pipe, allowing Pipelife to tailor our pipes to the specific needs of our customers. Pipe production can begin with a SDR class of 26, and be changed to SDR30 in the middle of the pipe with a gradual transition between classes. This unique feature allows the production of pipe to unique specifications, such as 500 m long OD2500 mm pipe with 200 m of SDR26 and 300 m of SDR30. This feature provides flexibility and financial savings, while maintaining all the benefits of long length pipe and allowing for the provision of thicker wall in sensitive areas

Picture 2 - Departure of eleven OD1600 and OD2100 mm pipes, lengths between 500-600m.

3.5 Pipe delivery by sea

Pipelife's towing delivery method is both effective and safe – we have done it for 50 years. The pipe sections, normally up to maximum 600 m, are sealed off at both ends with PE end plugs or flange connections. The closed pipe sections are then towed by tugboat to the marine destination.

4. Fittings range

Pipelife has developed a complete range of fittings which enables the delivery of the complete pipe system, with a special focus on marine projects. Solutions have been developed for all parts of the pipeline: connection to concrete structures, pipe connections, t-pieces, bends, manholes and diffusors. These solutions guarantee longevity, and excellent quality throughout the lifetime of the project, even for the largest pipes (OD2500 mm).

4.1 Electrofusion saddles

The electrofusion PE saddles have been developed as an answer to the need for safe and corrosion free solutions for manholes and diffusors. Saddles use an in-house developed electrofusion method to safely secure the manhole to the main pipe.

Welded saddles have been pressure tested in full scale up to 2 bar to confirm the quality of the weld.

Picture 3 - Full scale pressure test of OD1000 saddle on OD2500 pipe to 2 bar

Saddles are available in the following sizes:

Table 1 - Available sizes of Electrofusion Saddle

Pipe size	Inlet size												
	355	400	450	500	560	630	710	800	900	1000	1200	1400	1600
900		☑											
1000	☑		☑	☑	☑								
1200	☑			☑	☑	☑	☑						
1300				☑	☑	☑	☑	☑					
1400				☑	☑	☑	☑	☑	☑				
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2100				☑	☑	☑	☑	☑	☑	☑	☑		
2300				☑	☑	☑	☑	☑	☑	☑	☑	☑	
2500				☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

Picture 4 - Preparing the saddle for welding on site

4.2 PE Fittings

Fittings are produced as segment welded parts to form a smooth transition and ensure optimal flow at all angles. Production takes place in a welding workshop located at the plant. The workshop is equipped with various welding tables, machines, tools and saws which enable the production of any fitting up to OD2500 mm size with the only limitations being the transport to the project location.

Various fitting types include: bends, T-pieces, manhole and diffusor risers, puddle flange fittings and others.

All produced fittings are unique and tailor-made to suit each specific project's requirements. Pipelife develops a 3D model and makes a 3D assembly of the complete network.

Fittings are produced in accordance with these models, and thus fit perfectly to site requirements.

Picture 5 - OD2500 mm SDR26 puddle flange fitting

Picture 6 - OD2100 mm SDR26 bend

4.3 Special reinforced PE fittings

For occasions when it is necessary to increase the load bearing capacity and safety during installation, Pipelife has developed a special wrapping solution for the fittings. Wrapping protects sensitive weld areas and provides an extra layer of protection during transport, manipulation and installation.

Picture 7 - OD2000 mm T-piece with reinforcement

5. PE material properties

5.1 General

A solid form of polyethylene was created in 1935 by British chemists Eric Fawcett and Reginald Gibson. This discovery was used for the first time during the Second World War in pipes that were used for the protection of radar cables. PE pipes began to be used more extensively in the 1950s. The PE raw materials have been further developed over the years and the PE resins used for pipe extrusion today differ to a certain extent from the resins used in the early days. PE pipe manufacturers normally purchase PE resins compounded from the resin suppliers (i.e. with additives and pigments included) and do not add any further additives when extruding the pipes.

5.2 PE raw material classification

There are a number of standards used to classify PE materials for pipe extrusion. Today the most common materials used in Europe are PE80 and PE100, where the numbers refer to the long-term material strength according to EN standard. The ASTM standard for PE pipe resins classifies the strength properties of the different PE resins in a similar way, but refers to a cell classification for strength properties.

Pipelife uses special PE100 resins with low sag properties, specially made for the production of large diameter pipes.

5.3 PE pipe classification

A PE pipe is classified by the type of PE material from which the pipe has been extruded and the SDR ratio of the pipe (pipe OD/pipe wall thickness). Alternative ways to classify PE pipes include using PN and SN values.

For further information, please consult Pipelife.

5.4 PE material properties

PE materials for pipe manufacture are available in different material designations (PE 80 and PE 100).

Pipelife uses only a special variant of PE100 material for LLLD PE pipes with the following minimum requirements:

Table 2 - PE material properties

Characteristics	Standard	Required Value
Compound density	ISO 1183-2	≥ 930 kg/m^3
Carbon black content	ISO 6964	2 to 2.5% by mass
Carbon black dispersion	ISO 18553	≤ 3
Oxidation induction time (OIT)	ISO 11357-6	≥ 20 minutes at 200˚C
Water content	ISO 15512	≤ 300 mg/kg
Volatile content	EN 12099	≤ 350 mg/kg
Melt mass-flow rate (MFR)	ISO 1133 Condition T	0.2 to 1.4 g/10 minutes
Tensile strength for butt-fusion	ISO 13953	Ductile failure
Slow crack growth (110mm SDR11 pipe)	ISO 13479	≥ 500 hours
Elongation at break	ISO 6259	≥ 350 %
Hydrostatic strength at 80˚C	ISO 1167	≥ 165 hours at 5.4 MPa
Hydrostatic strength at 80˚C	ISO 1167	≥ 1000 hours at 5.0 MPa
Hydrostatic strength at 20˚C	ISO 1167	≥ 100 hours at 12.4 MPa
Allowable long term stress value	EN 12201-2	10 MPa
Design long term stress value	EN 12201-2	8 Mpa

The allowable stress in the pipe wall of a PE pipe is normally calculated with a design factor of 1.25 on the minimum required strength value according to EN 12201. This suggests that a PE 100 pipe, which is subjected to an internal pressure corresponding to its PN designation will experience a pipe wall stress of 8 MPa, and at this stress level a lifetime exceeding 100 years at the temperature +20°C is expected. If a pipe were to be subjected to a higher pressure than its PN designation for short periods of time, it may not necessarily lead to a decreased life expectancy. A PE pipe has a rather high short-term strength compared to its long-term strength (approx. 23-24 MPa at a few minutes of loading and approx. 13-15 MPa at 1 hour of loading). At short-term loading the real design factor is thus significantly higher. A PE pipe is therefore able to withstand higher pressures than its PN designation for short periods of time. An increased design factor will further increase the expected lifetime.

Table 3 - Pressure ratings

Class	S	MRS	C	Pressure rating (PN) for selected SDR class									
				33	30	26	22	21	17	13.6	11	9	7.4
PE100	8	10	1.25	5	5.5	6.4	7.7	8	10	12.5	16	20	25

MRS: Minimum Required Strength by ISO 9080-2; C: Safety factor; S: Design stress; SDR: Outside pipe diameter divided by wall thickness

The strength properties of a PE pipe are also dependent on the temperature, and strength properties are normally affected by temperatures of +20°C and above. Higher temperatures will reduce strength, lower temperatures will increase strength. For PE pipes to be used at temperatures higher than +20°C, the reduction factors given in table 3 can be used.

Table 4 - Strength reduction coefficients as per ISO 13761:1996

Temperature (°C)	20	25	30	35	40	45	50
Reduction factor for PE100	1.00	0.93	0.87	0.80	0.74	0.70	0.67

Table 5 - Representative E-modulus values for different types of PE pipes at +20°C

Type of material	Representative E-modulus values* (MPa)						
	3 min	1 h	10 h	100 h	1000 h	1 year	50 years
PE 100 (Stress level 4 MPa)	800	550	425	325	250	200	150

*) The value is dependant on the stress level in the pipe wall and the duration of loading.

5.5 E-modulus

The most important parameter for structural design in a PE pipe system is the modulus of elasticity (Young's modulus) of the PE material from which the pipe has been manufactured. Since PE is a visco-elastic material, the E-modulus for a PE pipe will not be constant as it is with inelastic materials (like steel), and appropriate values need to be selected from a set of curves or from tables.

The elongation properties of the pipe are determined by the E-modulus and many formulas used for the design of pipelines require a value for the E-modulus.The E-modulus for PE is influenced by the temperature, the duration of loading and the stress level in the material. A higher temperature will give a slightly decreased E-modulus and a lower temperature will give a slightly increased E-modulus. Representative E-modulus values for pipes of PE 100 resins are given in Table 5. The values given in Table 5 are related to a stress level of 4 MPa in PE 100 pipes respectively. At higher stress levels lower E-modulus values apply. At lower stress levels higher E-modulus values apply.

At temperatures lower than +20°C, E-modulus values will increase slightly. However, increased E-modulus values and increased strength properties at temperatures below +20°C are not normally considered when the pipe is being designed. Increased properties are utilized as a contribution to an increased design factor, and increased longevity.

5.6 Thermal expansion/anchoring of PE pipes

Temperature changes may give rise to a noticeable change in length for a PE pipeline; as a result of this change, movements in axial direction can occur. A PE pipeline with restrainable joints on supports can accommodate limited changes in length, for example minor movements and angular deflections in bends. However, fixing points should be placed close to each side of the bend in order to limit movements and angular deflections.

A thermal expansion coefficient of 0.16 – 0.18 mm/m°C can be used for the calculation of thermal movements in PE pipe systems.

If thermal movements are prohibited in a PE pipe, the prohibited expansion will give rise to axial forces in the pipeline. Almost all types of joints for PE pipes are restrainable, i.e. are able to transfer axial forces within the pipeline. Such forces are created by the internal pressure in the pipe and by temperature changes in the system. A pipe system which is able to transfer axial forces does not require thrust blocks, provided the joints are able to transfer the upcoming forces. Welded joints in PE pipes have almost the same strength as the pipe itself, and welded PE systems therefore normally only require:

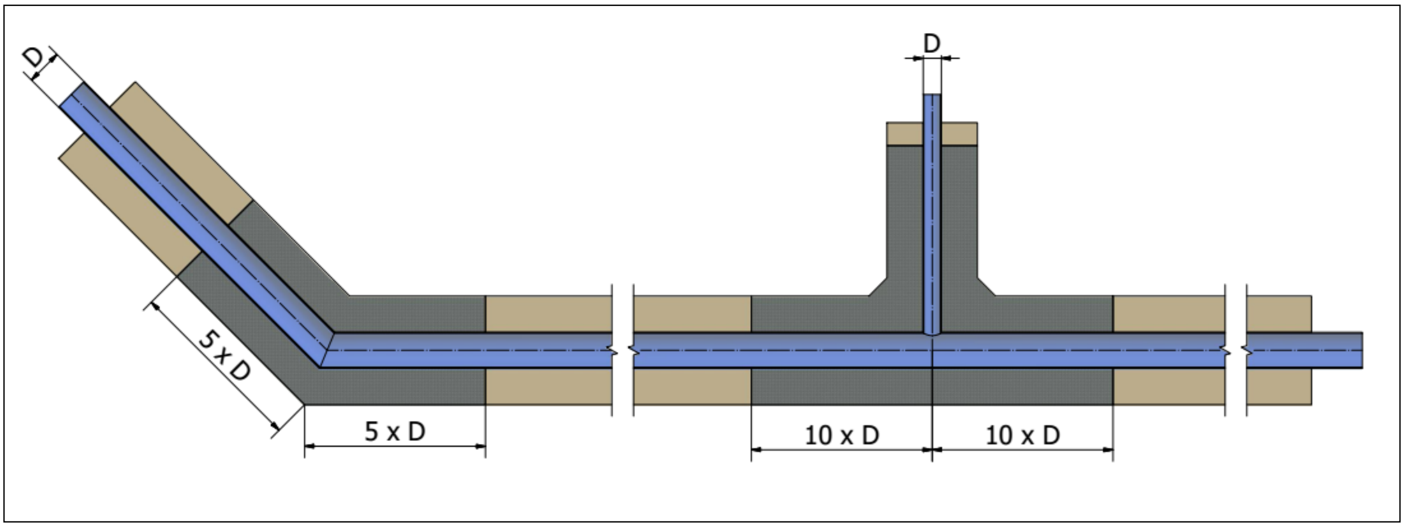
- anchoring of the PE pipe at connections to valve chambers and pumping stations, and at connections to bell and spigot jointed pipe systems
- anchoring at each side on bends for PE pipes placed on supports

The anchoring of the pipe ends of PE pipelines with welded joints is necessary because the internal pressure will cause a small diameter increase in the pipeline, and a corresponding shortening of the pipeline will occur unless the end points are anchored. Temperature changes may also give rise to changes in pipe length. The anchoring of the end points is especially important for PE pipe placed on supports, or laid in ducts. For a buried pipe, the soil friction will to a certain extent contribute to the anchoring of the pipe ends. However, for large diameter PE pipes a further anchoring of the pipe ends may be necessary, because soil friction may not be high enough to prohibit minor movements at the end points. Axial forces may thus be transferred from the pipe system to valve chambers and pumping stations. Connection points should therefore be designed to resist such forces, which can be large and may necessitate the welding of specific anchoring flanges on to the PE pipeline. Along with the anchorage of buried PE pipes in concrete walls, the risk for water leakage between the pipe and the surrounding concrete also needs to be considered. It is therefore recommended that the cast in the PE pipe section also has a water stop flange welded on to the PE pipe.

For this purpose, Pipelife has a special puddle flange fittings. To calculate the forces, please consult Pipelife.

Axial forces occurring as a result of the elongation of the pipe at assembly or due to temperature changes will decrease as a result of relaxation. The initial force is dependent on how fast and to what extent the pipe is elongated at assembly, and how fast a temperature change occurs in the pipe. To calculate initial forces the E-modulus is to be chosen in accordance with these conditions, See Table 5.

Figure 1 - Backfill with compacted friction material around bends and tees to minimize movements in buried PE pressure pipe systems



In order to minimize movements at bends and tees in buried PE pressure pipelines backfill of friction material should be placed as shown in Figure 1. The backfill material is to be compacted to > 90 % mod. Proctor in the following locations:

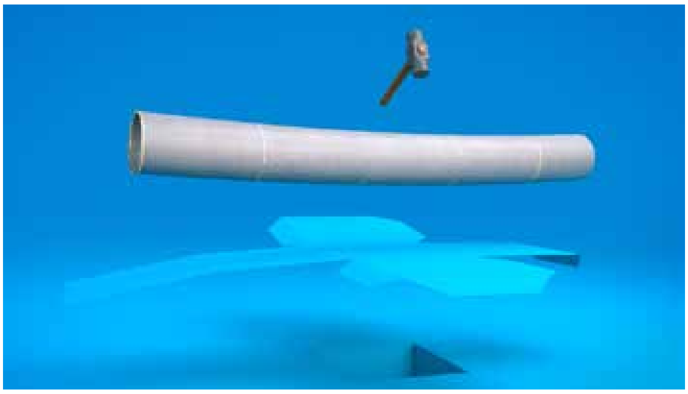
- all bends >10° at a distance of minimum 5 x OD on each side of the bend (if bends larger than 45° are substituted with two bends of half angle, an improved hydraulic function and a decreased soil pressure around the bend will be achieved.)
- all tees at a distance of minimum 10 x OD around the tee (where OD is the diameter of the branch)

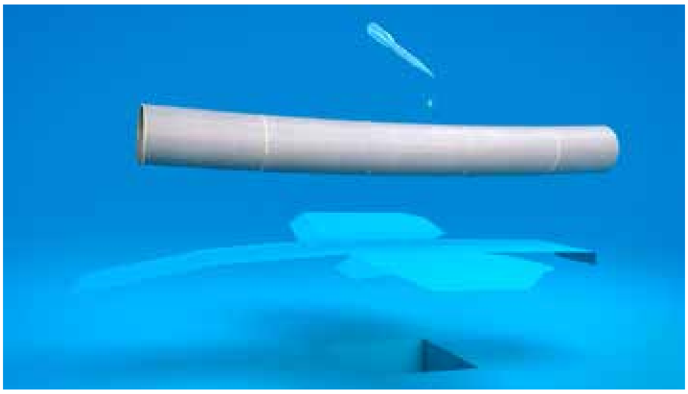
If backfill is placed and compacted as described above, movements are expected to be almost negligible (usually less than 1% of the pipe diameter).

Segment welded PE tees are sometimes cast in concrete as a protection for the tee fitting. If PE tees are cast in concrete, the surrounding concrete needs to be reinforced to withstand the full internal water pressure in the pipeline.

5.7 Diffusion

PE pipes are not completely diffusion tight against low molecular organic substances. This permeability differs for different types of PE materials, and increases with increasing temperatures. On rare occasions a taste and odour effect on the water has been found for small sized PE pipes in heavily contaminated ground. Reported problems are almost exclusively related to house connections of LDPE (low density polyethylene). PE80 and PE100 materials have a significantly higher diffusion resistance compared to LDPE materials. The time it takes for a substance to penetrate the wall of PE pipes of the same SDR ratio is directly proportional to the square of the pipe wall thickness. It thus takes 100 times longer to notice any taste and odour influence in a 250 mm pipe than in a 25 mm pipe of the same PE material and SDR rating. Furthermore, stagnant water is much more common in house connections than in distribution lines. The circumference/volume ratio of the pipe will also affect the risk of taste and odour problems. For small diameter pipes with a large surface disproportionate to the pipe volume, the concentration of permeating substances will be higher than in larger pipelines. Thus, taste and odour problems are only found in small diameter PE pipes. If small diameter PE pipes need to be installed in contaminated ground, pipes with a diffusion barrier can be chosen, but in most cases larger PE pipes do not need any additional protection even if installed in contaminated ground.





5.8 Notch sensivity

PE pipes are relatively soft and can be scratched if carelessly handled. Normal handling will only result in minor scratches, which will not influence the strength properties of the pipes. Scratches on PE pipes may appear worse than they really are. The real depth of a scratch can be measured using a measuring device.

Scratches up to a depth of 10 % of the pipe wall thickness do not affect the strength properties of a PE pipe. Therefore, in most cases it is of little consequence which type of PE pipe is used for the pipe manufacture. The development of new PE resins has ensured that crack resistant PE materials are now available, for which scratches have even less influence on the strength properties of the pipes. If it is desired that the possible effects of scratches are minimized, such resins can be used for the manufacture of the pipes.

For further information, please consult Pipelife.

5.9 Abrasion resistance

PE pipes have better abrasion resistance than most other pipe material and PE pipes are often used for slurry pipelines in the mining industry. The abrasion in the pipe is dependent on the size, shape and concentration of the solids in the slurry as well as the angle of impact and the flow characteristics.

For further information, please consult Pipelife.

5.10 Chemical resistance

PE pipes are resistant to most chemicals, salts, acids and alkalis. However, petroleum products could cause a slight swelling of the PE material. Wetting agents and strong oxidizing liquids will impair the stress cracking resistance of PE and shorten the lifetime of the pipes. Information on the extent to which different chemicals may affect the lifetime of PE pipes can be found in chemical resistance tables published by various PE resin manufacturers and plastic pipe organisations.

For further information, please consult Pipelife.

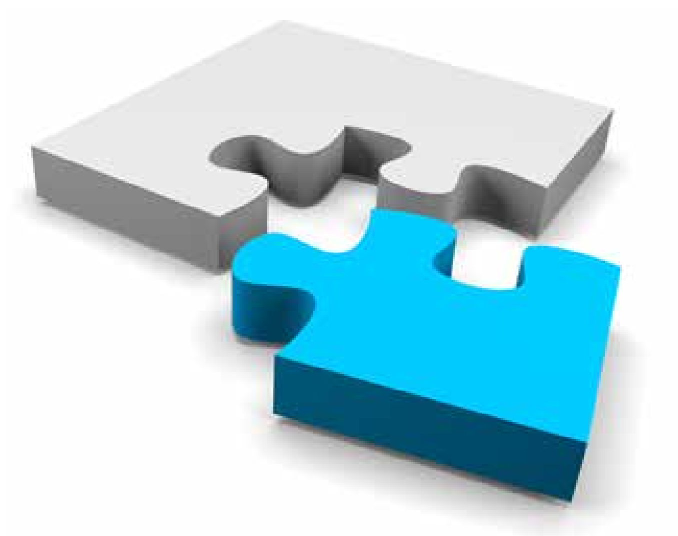
6. Welding

Welding is an integral part of every project, therefore Pipelife has invested substantial resources in determining the best possible procedure and parameters with constant improvement across the field.

The welding is performed by certified welders with many years of experience in the field. In addition, Pipelife currently operates a complete fleet of butt fusion welding machines covering the whole pipe range.

6.1 Butt fusion welding

Pipelife Norge follows the standard DS-INF70 for butt fusion welding. Currently, there is no standard available which covers butt fusion welding for solid wall pipes larger then Ø2000 mm. Pipelife has therefore developed its own private welding procedure, based on DS-INF70 which has been successfully used for decades and in many projects. With production capabilities ahead of standards development, Pipelife has been pioneering the welding process of large (>OD2000 mm) solid wall pipes.

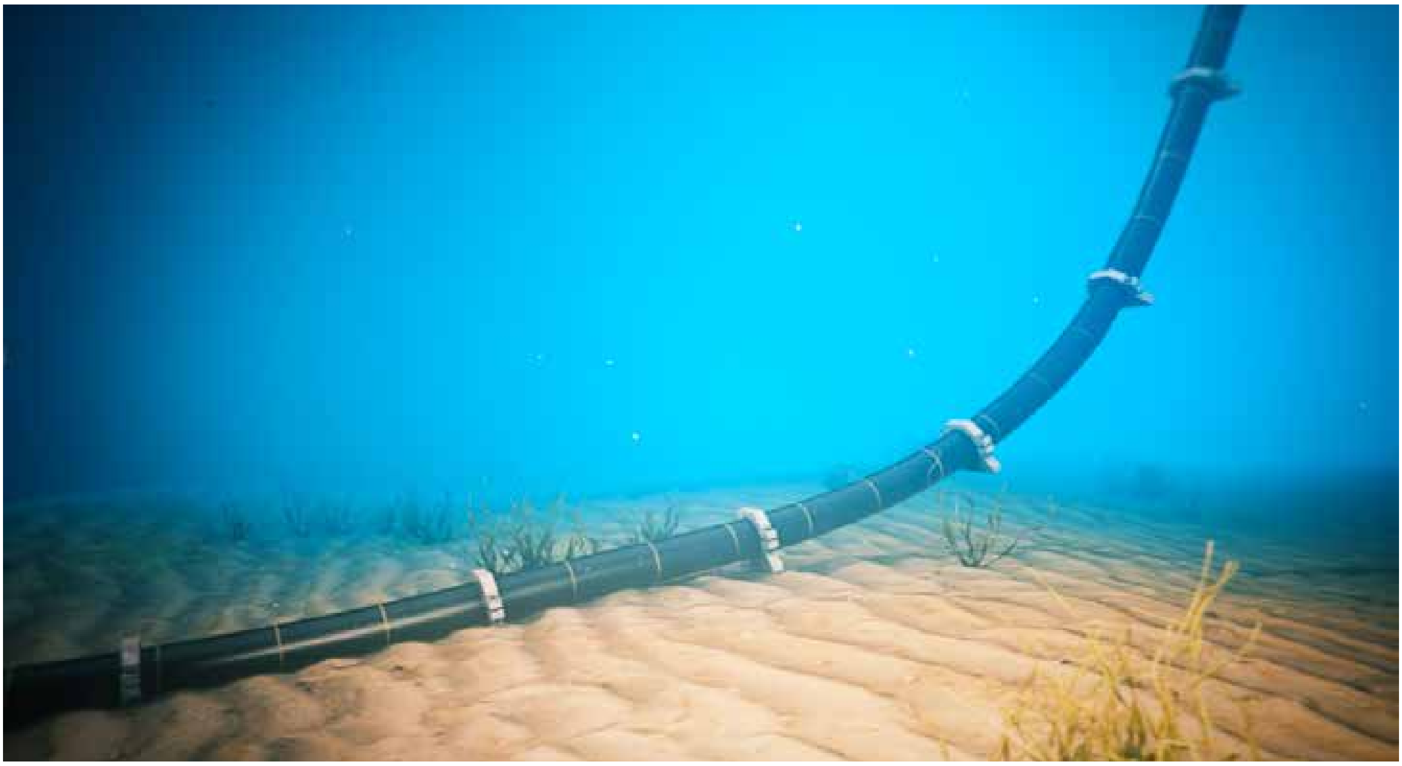


7. Advantages of LLLD concept

The LLLD concept offers a cost effective and easy to install solution for offshore and near shore projects but requires a high degree of expertise and a focus on detail.

- With long length pipe delivery, no welding/jointing work on site is needed. If supplied in short lengths, lengthy welding work would be required.
- Significantly reduced risk of bad welds, as very few welds are carried out on our long length pipes, and any necessary welds are carried out by Pipelife specialists.
- No risks of ovalisation, as the pipes are stored in the sea. Due to the temperature difference, the pipes will also rotate in the water, which additionally ensures the roundness of the pipes.
- No need for an on-land storage. Storing pipes on land would require large area as well as stacking limitations of pipes based on pipe size.
- Easier handling of stored pipes.
- Limited environmental impact as pipes are stored and handled mostly on the sea.
- Much lower risk of scratches and other damage to the pipes.
- Short installation time, and thus low installation cost. All the pipe sections are supplied with flange connections and blind flanges already on the pipe ends, so the assembly work is done at our plant. Thus, costs for the contractor are reduced.
- As a result, the overall safety of the installed pipe system is increased. This is of great importance to both the contractor and the client of the project.

Pipelife is focused on providing a complete system solution with engineering support based on years of experience in marine projects worldwide.



8. Focus on marine projects

The Pipelife LLLD concept is best suited for marine projects, outfalls and intakes for various purposes: power generation, desalinization, sewer outfalls, sea water air conditioning, LNG terminals and floating LNG, industrial outfalls and intakes.

Solid wall PE pipes have an outstanding track record in marine pipe projects. Current limitations are:

- Maximum pipe size is OD2500 mm
- Maximum supplied length for an OD2500 mm pipe is 620 m
- Installation depth up to 900 m depending on the pipe size and SDR ratio

8.1 Marine installations

The “S-bend installation method” (also known as “Float and sink”) is a fast and economical installation method, which has been practised since the 1950s. During installation, the PE pipe can be extensively bent, and the pipe may be subjected to higher stresses and strains than it will for the subsequent duration of its service life. Consequently, in order to be able to provide a good structural pipeline design, the designer ought to have a basic knowledge of marine PE pipeline installation issues.

The high degree of flexibility of PE pipes is utilized during the submersion process. PE pipes can be subjected to up to 5 % strain without overstressing the material. This strain level is reached when the pipe is bent to a radius of 10 times the OD of the pipe. Therefore, it is primarily the risk of kinking in the pipe, rather than overstressing which limits the bending radius during submersion. Kinking, i.e. a rapidly increasing ovality in the pipe due to bending resulting finally in a folding of the pipe, will occur if the pipeline is bent excessively. The degree of bending at which kinking starts depends on the SDR class of the pipe. If the start of kinking is defined as when the pipe has reached 8 % ovality due to bending, kinking will start when a bending radius of approximately () is reached. Table 6 below shows the bending radius and the corresponding strain value in the pipe when the pipe has achieved 8 % ovality due to bending.

Table 6 - Bending radius and strain in pipe wall when a PE pipe has reached 8 % ovality due to bending

SDR value	Bending radius/OD	Strain in pipe wall (%)
33	27	1.8
26	22	2.3
21	17	2.9
17	14	3.5
13.6	11	4.4
11	9	5.5

As can be seen from Table 5, kinking will occur before a strain level of 5 % is reached for all SDR classes higher than 11. To ensure a safe installation of a PE pipe utilizing the S-bend sinking procedure, the bending radius must be closely monitored during the submersion process. The bending radius is dependant on the SDR ratio, the amount of weighting on the pipe, the installation depth, the wave height during the submersion operation, the submersion speed and the pulling force applied on the floating end of the pipe.

The sinking of a PE Pipe is usually in the range of 500-700 m/h, enabling that the submersion operation can be safely controlled. Since the bend progressively moves along the pipeline, the bending stress will normally act on the pipe as a short-term stress (lasting only a few minutes). Since PE is a viscoelastic material, the material will creep when subjected to stresses, see Paragraph 5.5. Furthermore, the creep in the PE material will lead to the increase in the bending of the pipe if the submersion operation is stopped or slowed down. Taking the above into consideration it is advisable to have a safety factor against kinking of minimum 1.5. Furthermore, it is also advisable not to subject PE pipes to fast short-term bending which could give strain values exceeding 2 % in the pipe wall. Thus a bending radius of less than 25 times OD should not be accepted during the sinking operation even for thick walled pipe.

For PE outfalls, operating at an internal pressure of less than 4 bar, a SDR 26 pipe will in most cases be the optimal choice. SDR 26 pipe can be bent down to a radius of 30-40 times the diameter during installation, whilst still providing a high safety factor.

Recommended minimum bending radii for PE pipes of different SDR classes are:

Table 7 – Minimum recommended short term bending radius/OD

SDR class	Minimum recommended short term short term bending radius/OD
30	37
26	33
21 or lower	25

In order to safeguard deep installations it is advisable to have the contractor present his method of installation, calculation of bending radius and his monitoring system for the laying of the pipeline prior to the installation itself.

For further information, please consult Pipelife.

Picture 8. Passing the Bosphorus Channel

Picture 9 – Some examples of weight design for marine PE pipelines

8.2 Ballasting

PE has a density of around 960kg/m3; a PE pipe will thus float even when filled with water if it is not ballasted. The amount of ballasting required depends on the wave and current forces that may affect the pipe, and whether the pipeline is placed directly on the sea bed or in an open excavated trench (pipelines in an open trench may be somewhat sheltered by the trench).

The pipes must therefore have concrete weights attached to ensure a sufficient stability on the sea bed against wave and current forces. The amount of loading applied largely depends on the water depth and on the location of the pipeline. A common weighting is in the range of 20-45 % of the pipe's displacement, but even higher weighting may in some cases be required. There is a range of different weight shapes.

For pipes that are to be installed in trenches in the sea bed, the ballasting of the pipe is chosen with regard to the risk that the backfilling of the trench may affect the line and level of the pipes. A ballasting of 30-40 % is normally needed for such pipes, depending of pipe size and method of backfilling.

A PE pipe with concrete weights attached will in most cases, level itself on the sea bed. Thus, the the need for sea bed adjustments is normally minimal. A normal weight spacing is in the range of 3-6 m depending on the amount of loading and the pipe size.

There are two requirements, which have to be fulfilled for the concrete weights (except for continuos collars):

- The weights must be attached to the pipe in such a way that they do not slide on the pipe during the sinking operation.
- The weights must be able to take the forces to which they will be subjected from the PE pipe due to the internal pressure in the pipe.

If the weights slide on the pipe during the S-bend sinking operation, the whole operation may fail. The risk of sliding is reduced at shallow installation depths, but for pipes which are to be installed at great depths there is a significant risk of sliding, if the matter of attaching the weights has not been properly considered. It should also be noted that the diameter of the pipe might shrink during the sinking operation due to the decreased water temperature by depth and the longitudinal forces acting on the pipe during installation.

Proper design includes testing and selecting an adequate batch of elastic material (usually EPDM rubber) for compensators and inserts between ballast weights and HDPE pipe. In adittion, bolts and torque are also to be tested.

When a PE pipe is subjected to internal pressure the diameter of the pipe will increase over time. This expansion of the pipe will transfer forces to the concrete weights, and the weights must thus be reinforced to be able to withstand these forces. For outfalls operating at low pressures the forces transferred to the weights will be limited. However, for marine PE pressure lines, the weights must be designed to resist significant forces due to the expansion of the pipes.

For further information, please consult Pipelife.

8.3 Trenching and backfilling

The load bearing capacity of PE pipes installed in trenches depends on the SDR rating of the PE pipe, the external loads and the material and compaction of the surrounding backfill material in the trench. For most PE intake and discharge pipelines, SDR ratings of 26-30 are used.

PE SDR 26 and SDR 30 pipes can be buried in trenches in the seabed with a cover of up to 5 m if backfilling of sand, gravel or crushed rock (grain size < 38 mm). The method of installation of the backfill should be chosen carefully in order to minimize the risk of internal material separation during installation. The method of installation must also enable the backfill material to completely surround the whole pipe, including the parts under the haunches of the pipe. The backfill material should reach at least 0.4 m above the top of the pipe. Excavated material can be used, but is subject to proper engineering and design of the whole system. Deeper installations or other backfill materials will require further calculations to check if a sufficient safety against pipe buckling can be achieved.

For further information, please consult Pipelife.

Picture 10 - Beginning of submerging of OD2500 mm SDR26 pipe

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9. Engineering support

Over the years, Pipelife has developed a wealth of specialist knowledge from its role in challenging projects located around the world, dealing with project requirements, different installation designs and methods. Many of Pipelife's projects have been completed with assistance from the world's best consultants, engineers and many others, leaving a legacy of good design decisions and successful installations.

Pipelife is committed to providing a complete system solution. With its extensive resources Pipelife can offer engineering and general technical advice to designers, consultants, marine contractors, EPC contractors or end clients on various issues as specified in 9.1 and 9.2.

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9.1 Design guidelines

- Determining appropriate SDR pipe class
- Review of hydraulic design: hydraulic roughness, head losses, transient and operating under pressures, ovalization, etc.
- Design of wave and current forces
- Design of weighting (ballasting) system: wave and current forces, size, shape and spacing of blocks and block details including drawings for construction and reinforcements
- Proposal for towing head and bend restrictors
- Calculating flange connection forces and procedure for spool piecing
- Review of detailed design, drawings and method statements
- Design of corrosion protection system (sacrificial anodes)
- Calculation of pipe/soil interaction and defining backfill

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9.2 Installation guidelines

- Analysis of installation through a purpose created computer program
- Determining required pull and air pressure
- Determining flooding by pumping with elevated air pressure procedure
- Determining valves for flooding and air venting
- Determining basic recommendations for an installation method statement
- Review of drawings and method statement for pipe installation
- Review of design details due to changes in procedures and on-going support until the project is successfully implemented

For more information please contact Pipelife as each project has unique requirements and specifications.

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10. Selection of SDR class

A marine PE pipeline must be designed to resist the stresses and strains to which the pipeline will be subjected during the installation of the pipe, and the external and internal forces the pipeline will be subjected to during its service life.

Various load cases which will affect the selection of SDR class are:

- Out of roundness/buckling due to bending of the pipe
- Pipe buckling of buried pipes
- Expected out of roundness for buried pipes
- Pipe buckling without external support
- Loads on marine PE pipes in trenches
- Tightness testing of PE pipes

The designer should select an appropriate SDR value for the pipeline with regard to relevant loads.

For further information, please consult Pipelife.

11. Tolerances in production

11.1 Pipe production tolerances

Values for ovality and wall thickness are based on EN 12201:2011. For pipes larger than OD900 mm Pipelife has adopted the written values as maximum. It is worth noting that Pipelife's production technique enables the production of OD 2500 mm pipe with an average ovality lower than 1.5% compared to declared maximum of 3.5%.

Table 8 - Maximum out of roundness

Nominal size	Nominal outside diameter	Mean outside diameter		Maximum out-of-roundness (ovality)
$DN/OD\ (mm)$	$d_n\ (mm)$	$d_{em,min}\ (mm)$	$d_{em,max}\ (mm)$	(mm)
355	355	355	357.2	12.5
400	400	400	402.4	14.0
450	450	450	452.7	15.6
500	500	500	503.0	17.5
560	560	560	563.4	19.6
630	630	630	633.8	22.1
710	710	710	716.4	24.9
800	800	800	807.2	28.0
900	900	900	908.1	*31.5*[2]
1000	1000	1000	1009.0	*35.0*[2]
1200	1200	1200	1210.8	*42.0*[2]
1400	1400	1400	1412.6	*49.0*[2]
1600	1600	1600	1614.4	*56.0*[2]
1800	1800	1800	1816.2	*63.0*[2]
2000	2000	2000	2018.0	*70.0*[2]
2100[1]	*2100*	*2100*	*2118.9*	*73.5*[2]
2300[1]	*2300*	*2300*	*2320.7*	*80.5*[2]
2500	2500	2500	2522,5	*87,5*[2]

[1] *Dimensions are not part of standard EN 12201-2:2011+A1:2013.*

[2] *Values are not present in current standard and are calculated as explained above.*

Wall thickness minimum and maximum values are obtained from EN 12201-2:2011+A1:2013. For SDR30 pipes values[3] are calculated per ISO 11922-1:1997 formula: $e = 0{,}1e_{min} + 0{,}1\ (mm)$.

To calculate each dimension[4], the formula as per ISO 11922-1:1997 was used: $e = 0{,}15e_{min}$

Table 9 - Maximum and minimum wall thicknesses

Pipe series								
	SDR 21		SDR 26		*SDR 30*		SDR 33	
Nominal pressure, PN in bar								
PE100	PN 8		PN 6		PN 5.5		PN 5	
Nom. Size DN/OD	Wall thicknesses							
	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}
355	16.9	18.7	13.6	15.1	*11.8*	*13.1*[2]	10.9	12.1
400	19.1	21.2	15.3	17.0	*13.3*	*14.7*[2]	12.3	13.7
450	21.5	23.8	17.2	19.1	*15.0*	*16.6*[2]	13.8	15.3
500	23.9	26.4	19.1	21.2	*16.7*	*18.5*[2]	15.3	17.0
560	26.7	29.5	21.4	23.7	*18.7*	*20.7*[2]	17.2	19.1
630	30.0	33.1	24.1	26.7	*21.0*	*23.2*[2]	19.3	21.4
710	33.9	37.4	27.2	30.1	*23.7*	*26.2*[2]	21.8	24.1
800	38.1	42.1	30.6	33.8	*26.7*	*29.5*[2]	24.5	27.1
900	42.9	47.3	34.4	38.3	*30.0*	*34.5*[3]	27.6	30.5
1000	47.7	52.6	38.2	42.2	*33.3*	*38.3*[3]	30.6	33.5
1200	57.2	63.1	45.9	50.6	*40.0*	*46.0*[3]	36.7	40.5
1400	66.7	73.5	53.5	59.0	*46.7*	*53.8*[3]	42.9	47.3
1600	76.2	84.0	61.2	67.5	*53.3*	*61.3*[3]	49.0	54.0
1800	85.8	94.5	68.8	75.8	*60.0*	*69.0*[3]	55.1	60.8
2000	95.3	105.0	76.4	84.2	*66.7*	*76.8*[3]	61.2	67.5
2100[1]	100.0	115.0[4]	80.8	93.0[4]	70.0	80.5[4]	63.6	73.2[4]
2300[1]	109.5	126.0[4]	88.5	101.8[4]	76.7	88.3[4]	69.7	80.2[4]

[1] Dimensions are not part of standard EN 12201-2:2011+A1:2013.

[2] Values are not present in current standard and are calculated as explained above.

[3] Values are not present in current standard and are calculated as explained above.

[4] Values are not present in current standard and are calculated as explained above.

In addition to geometry, during the production of long length HDPE pipes, the following length tolerances are required:

- For pipe lengths <100m: 0 to +2 m
- For pipe lengths >100m: 0 to +5 m

11.2 Fittings production tolerances

During the production of HDPE fittings, certain tolerances are necessary due to planning, welding and pipe production tolerances. Pipelife has adopted the following guidelines during fittings productions:

- For fittings and segments <Ø630: ±30 mm
- For fittings and segments >Ø710: ±50 mm
- For angle: ±3°
- All other according to EN 12201-3:2011

12. Disclaimer

The statements and recommendations made in this brochure are based on general assumptions and must not be considered as instructions, advice or guidelines for every individual situation. Pipelife cannot be held responsible in any way for the results of using and following the statements and recommendations made in this brochure. We especially dissuade non-professionals and consumers from operating based on the general statements and recommendations herein without any specific instructions from us or a professional. To prevent potential damages, we strongly recommend that you consult on your individual situation with us.

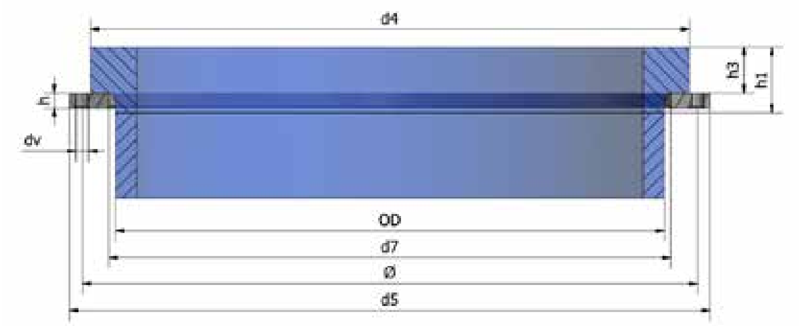
If you have any queries relating to this statement, please do not hesitate to contact us.

Picture 11 - Innovative on site transport of OD2100 mm in Morocco

13. Enclosure 1: Pipe production range

OD	SDR CLASS								
	33	30	26	21	17	13.6	11	9	7.4
	WALL THICKNESS								
(mm)	e (mm)	e (mm)	e (mm)	e (mm)	e (mm)	e (mm)	e (mm)	e (mm)	e (mm)
40				2.0	2.4	3.0	3.7	4.5	5.5
50			2.0	2.4	3.0	3.7	4.6	5.6	6.9
63			2.5	3.0	3.8	4.7	5.8	7.1	8.6
75			2.9	3.6	4.5	5.6	6.8	8.4	10.3
90			3.5	4.3	5.4	6.7	8.2	10.1	12.3
110		3.7	4.2	5.3	6.6	8.1	10.0	12.3	15.1
125		4.2	4.8	6.0	7.4	9.2	11.4	14.0	17.1
140		4.7	5.4	6.7	8.3	10.3	12.7	15.7	19.2
160		5.3	6.2	7.7	9.5	11.8	14.6	17.9	21.9
180		6.0	6.9	8.6	10.7	13.3	16.4	20.1	24.6
200		6.7	7.7	9.6	11.9	14.7	18.2	22.4	27.4
225		7.5	8.6	10.8	13.4	16.6	20.5	25.2	30.8
250		8.3	9.6	11.9	14.8	18.4	22.7	27.9	34.2
280		9.3	10.7	13.4	16.6	20.6	25.4	31.3	38.3
315	9.7	10.5	12.1	15.0	18.7	23.2	28.6	35.2	43.1
355	10.9	11.8	13.6	16.9	21.1	26.1	32.2	39.7	48.5
400	12.3	13.3	15.3	19.1	23.7	29.4	36.3	44.7	54.7
450	13.8	15.0	17.2	21.5	26.7	33.1	40.9	50.3	61.5
500	15.3	16.7	19.1	23.9	29.7	36.8	45.4	55.8	
560	17.2	18.7	21.4	26.7	33.2	41.2	50.8	62.5	
600	18.4	20.0	22.9	28.6	35.6	44.1	54.4	67.0	
630	19.3	21.0	24.1	30.0	37.4	46.3	57.2	70.3	
710	21.8	23.7	27.2	33.9	42.1	52.2	64.5	79.3	
800	24.5	26.7	30.6	38.1	47.4	58.8	72.6	89.3	
900	27.6	30.0	34.4	42.9	53.3	66.1	81.7		
1000	30.6	33.3	38.2	47.7	59.3	73.5	90.8		
1100	33.8	36.7	42.0	52.4	65.2	80.9	99.8		
1200	36.7	40.0	45.9	57.2	71.1	88.2			
1300	39.9	43.3	49.7	61.9	77.0	95.6			
1400	42.9	46.7	53.5	66.7	83.0	102.8			
1600	49.0	53.3	61.2	76.2	94.8				
1800	55.1	60.0	68.8	85.8	106.6				
2000	61.2	66.7	76.4	95.3					
2100	64.5	70.0	80.3	100.0					
2300	70.6	76.7	87.9						
2500	76.5	83.3	95.5						
2800	86.1	93.4	107.1						
3000	92.2	100.0	114.7						
3250	99.9	108.4	124.2						
3500	107.6	116.7	133.8						

14. Enclosure 2: Flange connection table



Stub ends											Backing rings						Bolt sets		
OD	DN	d4	SDR33		SDR26		SDR17		SDR11					PN2	PN10				
mm	mm	mm	h1	h3	h1	h3	h1	h3	h1	h3	d5	d7	Ø	h	h	r	hole	M	dv
20	15	45							35	10	95	32	65		14	2	4	12	14
25	20	58							35	9	105	38	75		14	2	4	12	14
32	25	68							35	10	115	48	85		16	2	4	12	14
40	32	78					40	11	40	11	140	55	100		16	2	4	16	18
50	40	88					60	12	60	12	150	66	110		16	2	4	16	18
63	50	102					75	14	75	14	165	78	125		16	2	4	16	18
75	65	122					80	16	80	16	185	92	145		16	2	4	16	18
90	80	138					90	17	90	17	200	108	160		18	2	8	16	18
110	100	158			80	26	100	18	100	18	220	128	180		18	2	8	16	18
125	100	158			80	28	110	18	110	25	220	135	180		18	2	8	16	18
140	125	188			80	30	120	18	120	25	250	155	210		18	3	8	16	18
160	150	212			80	30	130	18	130	25	285	178	240		18	3	8	20	23
180	150	212			80	32	140	20	140	30	285	188	240		18	3	8	20	23
200	200	268	100	32	100	32	145	24	145	32	340	235	295		20	5	8	20	23
225	200	268	100	32	100	32	150	24	150	32	340	238	295		20	3	8	20	23
250	250	320	100	32	100	32	160	25	160	35	395	288	350		22	5	12	20	23
280	250	320	100	34	100	34	170	25	170	35	395	294	350		26	3	12	20	23
315	300	370	100	36	100	36	190	25	190	35	445	338	400		26	5	12	20	23
355	350	430	110	40	110	40	110	30/50	205	66/40	505	376	460		28	4	16	20	23
400	400	482	120	44	120	44	120	33/54	220	72/46	565	430	515		32	4	16	24	27
450	450	535	120	44	120	44	120	56	120	74	615	465	565		36	6	20	24	27
500	500	585	120	47	120	47	120	58	120	76	670	533	620		36	6	20	24	27
560	600	685	120	50	120	50	120	60	120	80	780	575	725	35	44	7	20	27	30
600	600	690	85	45	92	52	100	60	110	73	780	615	725	35	44	7	20	27	30
630	600	690	120	56	120	56	120	64	120	82	835	645	725	35	44	7	20	27	30
710	700	805	120	60	120	60	120	70	120	85	895	725	840	35	50	7	24	27	30
800	800	900	120	77	120	77	120	85	120	95	1015	815	950	35	56	7	24	30	33
900	900	1005	120	88	120	86	120	90			1115	915	1050	35	68	7	28	30	33
1000	1000	1110	140	96	140	96	140	100			1230	1015	1160	35		7	28	33	36
1100	1200	1330	160	100	175	100	160	120			1455	1115	1380	35		7	32	36	39
1200	1200	1330	160	100	160	100	160	120			1455	1215	1380	35		7	32	36	39
1300	1400	1535	180	110	180	110	180	130			1675	1440	1590	42		10	36	39	42
1400	1400	1535	180	110	180	110	180	130			1675	1440	1590	42		10	36	39	42
1600	1600	1760	190	115	190	115	190	140			1915	1650	1820	50		10	40	45	48
1800	1800	1965	215	120	215	120					2115	1860	2020	50		10	44	45	48
2000	2000	2165	240	140	240	140					2325	2060	2230	55		10	48	45	48
2100	2100	2290	240	150	240	150					2440	2160	2340	55			48	45	48
2300	2300	2500	250	160	270	180					2680	2360	2570	60			52	52	56
2500	2500	2730	270	180	300	210					2920	2560	2804	70			58	52	56

15 Enclosure 3: Pipelife marine project references

Pipelife has successfully delivered over 125 major projects in 40 different countries. Pipes have been towed from Norway to destinations as far as: Uruguay, the Dominican Republic, Brazil, Colombia, Ghana, Algeria, Morocco, Ukraine and Cyprus.

One interesting project from each application is presented below.

For the full list, please consult latest Pipelife LLLD HDPE Reference list.

15.1 Power Plant Project highlight

RAS DJINET, 1131 MW COMBINED CYCLE POWERPLANT, ALGERIA, 2014.

EPC project by Daewoo E&C, Korea

Project worth: 1.1 billion $

Delivery of LLLD PE pipes and fittings OD2500, SDR26&30, 4500+ m and engineering assistance

15.2 Sewer outfall project highlight

HARROWSIDE SEA OUTFALL, UK, 2015.

Main contractor: J. Murphy & Sons, UK.

Marine contractor: Land & Marine Engineering, UK

Project worth: 100 million £

Delivery of LLLD PE pipes and fittings OD2100, SDR26, 1000m

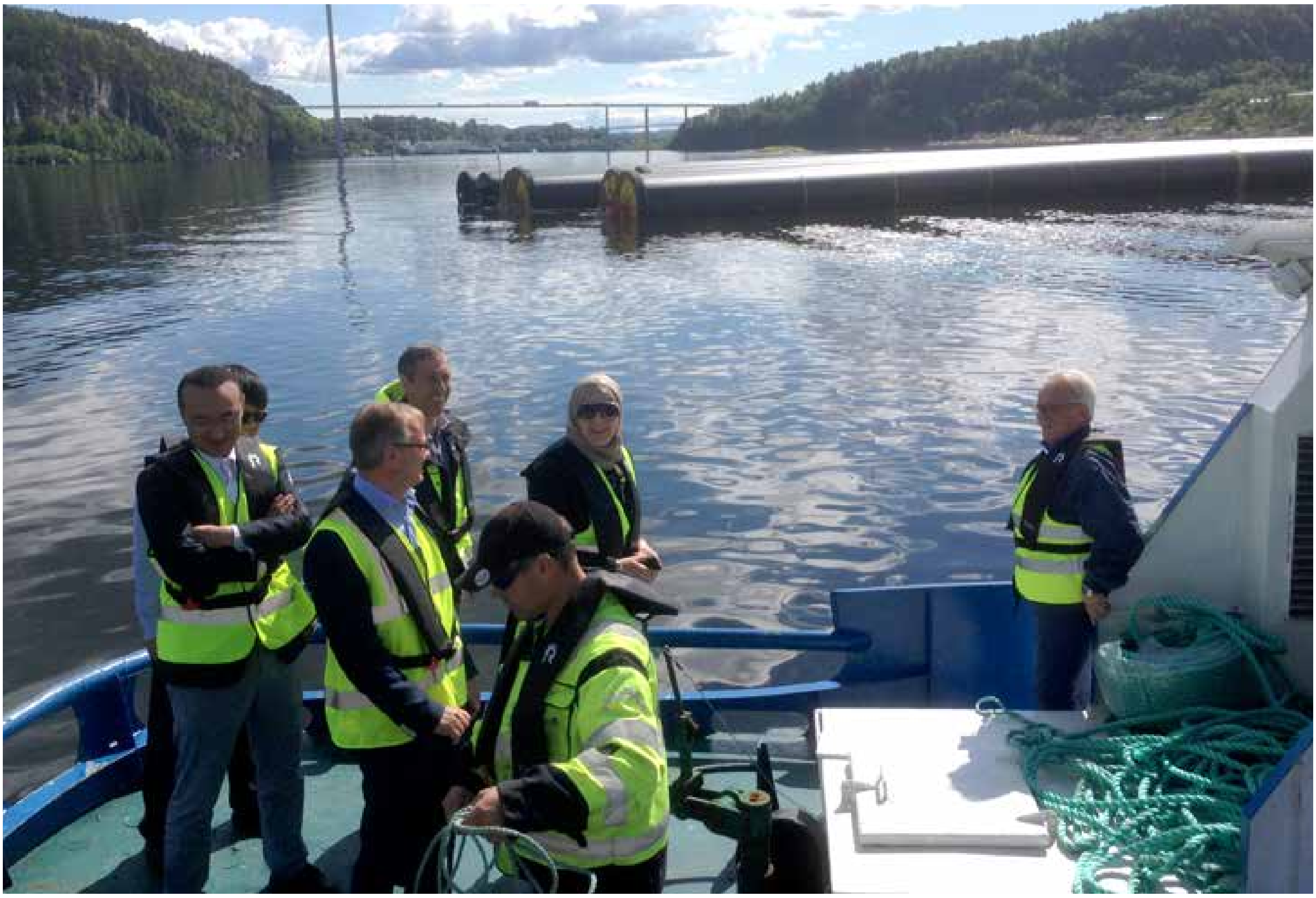
15.3 Desalination project highlight

CAMPO DE DALÍAS REVERSE OSMOSIS DESALINATION PLANT, SPAIN, 2013.

Main contractor: Veolia Water Technologies, Spain

Project worth: 110 million €

Delivery of LLLD PE pipes and fittings OD1800, SDR17&33, 1500+ m and OD1400, SDR17&33, 1850+ m.



Picture 12 and 13 - Inspection of the OD2500 mm SDR26 pipes delivered for the projects in Algeria and Ghana

LLLD PE pipes have many advantages and provide positive environmental benefits through smart transportation, installation and long lifespans.

Carbon Footprint

Green value chain

'The globe needs responsible users at every level. We simply have to reduce the depth of the negative footprints we are leaving behind - otherwise they will never be erased. PipeLife Norge AS wants to help to take charge, and enable our customers to do the same.

Our products are rarely seen, but are found everywhere. That is why it is so important that we take our environmental responsibilities seriously - the choices we make have a huge impact. The "right pipe" is, in our view, a pipe that has minimal environmental impact during manufacture and transport; that does not harm the environment during use; that is of good quality so as to prevent leakage; and is long-lasting, thus helping to reduce energy usage.

The term "Carbon Footprint" is used as a measurement of the total emission of carbon dioxide and methane from a business, individual or other entity. It takes into account not only direct emissions, from a factory for example, but also indirect emissions resulting from other factors such as the subcontractor production, transport, waste management, employee travel, etc. PipeLife Norge AS is proud that our carbon footprint is already relatively good, and we are working hard to achieve even better results. In order to reach this goal, we need to work on many levels, and look for improvements in the whole company. For further information, please consult Pipelife.

Pipelife Norway is Norway's largest producer and supplier of plastic pipe systems. The Pipelife Group is one of Europe's leading manufacturers of plastic pipes and associated parts. Our piping systems are used for water, sewage, gas, cable protection and electrical installations.

A significant proportion of our products are exported, particularly long length PE pipes in large diameters manufactured using Pipelife's unique production process at the Pipelife Norge AS plant in Stathelle, Norway. The factory has around 50 employees.

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